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Visualising Archaic Tombs and their Postdepositional Histories: The 3D Modelling of the Tombs from Cisterna Grande, Crustumerium (Rome, Italy)

Abstract: The Remembering the Dead project has been carrying out excavations in the Archaic cemetery of Cisterna Grande, Crustumerium (Rome, Italy) since 2004. The main aim of this project is to study virtual representations of a pre-Roman community. Methodologically, the project uses standard single context recording and most planning is done with a total station. All hand-drawn plans are transformed into a digital format. This integrated data is then used to build 3D models. The local volcanic geology and the continuing agricultural use of the area have resulted in the partial or total collapse of many of the tombs. The potential of virtual models to present these tombs and their postdepositional histories is discussed together with the pros and cons of using AutoCad, ArcGIS, 3D Studio Max, Bryce and Unreal Editor. Some examples of the ongoing modelling are presented.

Introduction

The Remembering the Dead project explores Cisterna Grande, one of the cemetery areas of Crustumerium (Rome, Italy). Under the auspices of this project, excavations started at Crustumerium in 2004 as part of a series of international excavations. The site of Crustumerium *(see Fig. 1)* is located in the Tiber valley about ten kilometres north of Rome. It was one of the rival city-states of Rome, which was defeated together with the neighbouring Fidenae in 500–499 BC The town declined and had vanished altogether by the fourth century BC (Quilici / Quilici Gigli 1980; di Gennaro 1999; Amoroso 2000). The area of Cisterna Grande was chosen for the excavations after recent illegal excavations. The first tombs exposed were chamber tombs and due to the rarity of their excavation, the project has concentrated on them ever since.

The excavations in the cemetery of Cisterna Grande are carried out in collaboration with the Superintendency of Rome and Dr di Gennaro, the director of this archaeological area. The main aim of the project is to study the metaphorical funerary

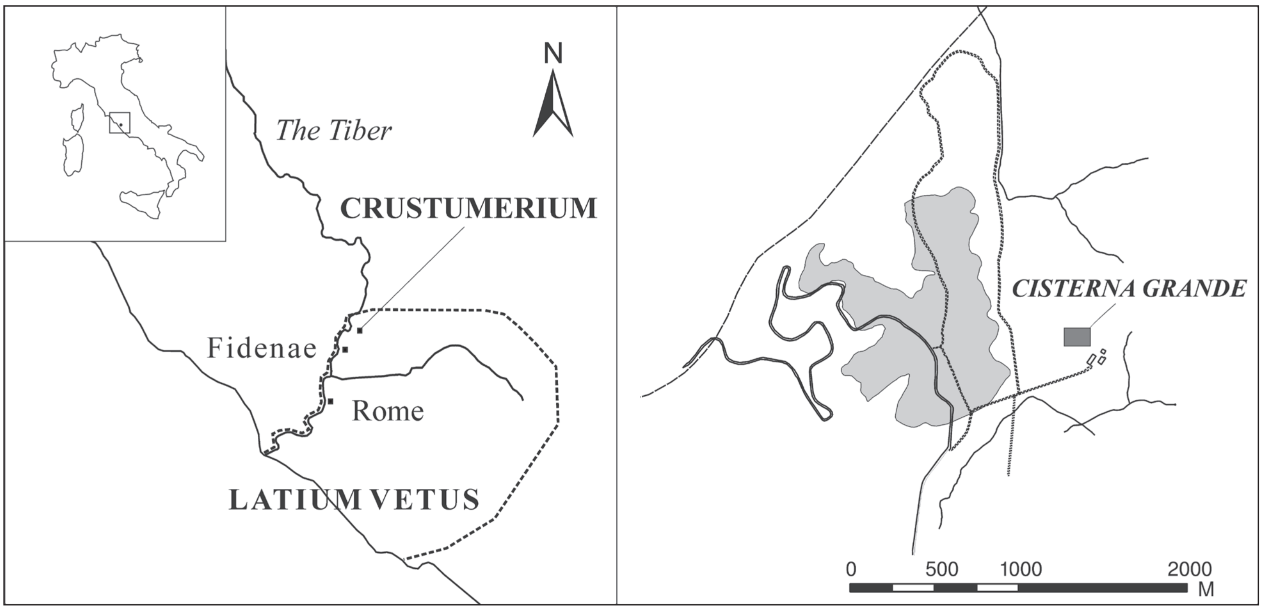

Fig. 1. The excavations of Cisterna Grande at Crustumerium (Rome, Italy).

representations of a Latin late Iron Age and Archaic community. The tombs form part of a wider ritual landscape that is studied using digital methods. In addition to digital single context planning, the project makes use of GIS and virtual modelling.

Chamber tombs were cut into volcanic tuff outside settlements from the mid seventh century BC (cf. DI GENNARO 1999). Chambers were normally rectangular room-like spaces, which were entered through a door via an entrance corridor (dromos). Many chambers had niches (loculi) carved into their walls. Chamber tombs were the dominant tomb type throughout the Archaic period, the sixth and fifth centuries BC They generally accommodated more than two bodies and are likely to have been family tombs. The chambers excavated so far at Cisterna Grande, although limited in number, present wider degrees of variability than expected.

This paper will present our recording strategy and how the data collected is used in virtual modelling. Different software options will be briefly compared. The possibilities for visualising the different postdepositional histories of the chambers will be examined and the importance of virtual modelling in reconstructing destroyed entities emphasised. As a final note models created using ArcGIS and 3D Studio Max will be presented.

Virtual Reality and Tombs in Archaeology

In Reilly's original discussion of Virtual Archaeology (REILLY 1991), it was stated that virtual models were replicas, the accuracy of which depends on the quality and quantity of available data. After a pilot project (DELOOZE / WOOD 1991), a considerable number of early projects were presented in the volume Virtual Archaeology (FORTE / SILIOTTI 1997). The usefulness of interactive simulations in VRML language was also promptly acknowledged (FORTE / GUIDAZZOLI 1996; GILLINGS / GOODRICK 1996).

Virtual modelling creates two types of models with two types of software. Surface modelling creates wire-frames or line models that can then be rendered. In the case of proper surface models, these frames are formed by polygons. Solid modelling creates a real three-dimensional representation of an object. Since it is a physical representation rather than a shell, it has properties like mass and volume (LOCK 2003, 152). Although the software integration is not perfect, much has changed since the earlier lack of proper user interfaces (DANIELS 1997). Processing capacity and memory are available to an extent unimaginable to past users. However, since surface models can be created with standard GIS and 3D modelling software, most models developed are of this type. Nevertheless, the contradiction between the hyperreal and the lack of some aspects of archaeological data must be recognised (BATEMAN 2000; EITELJORG 2000; KANTNER 2000).

Most of the early tomb models were wireframe presentations of Egyptian painted tombs based on architectural plans and created in VRML (GOTTARELLI 1996; PENDLEBURY 1996; TERRAS 1999). Brochtorff circle in Malta, however, was recreated in collaboration by the INSITE project of the Department of Computer Science at Bristol and the Brochtorff circle excavation project (CHALMERS ET AL. 2007). The archaeological basis of this work was an accurate DEM and photogrammatic survey of the site. The Maltese development work extended also to the underground burial complex of Hal Saflieni and its realistic lighting and texturing effects (cf. POPE / CHALMERS 2000). Some virtual models are based on Quicktime 360 grades photograph panoramas (CUMMINGS 2000; MAZZOLENI ET AL. IN PRESS), while other recent studies have experimented with the use of large volume laser scanners (e.g. TAYLOR ET AL. 2002).

Virtual models are generally constructed by computer scientists. Nevertheless, archaeologists are increasingly involved in modelling. Some models are based on old excavation data with height points taken from excavation plans, like Avern's Iron Age chariot burial (AVERN 2002), created in 3D Studio Max. Other projects produce their own data. For example, M Sepulcher and its paintings (FORTE ET AL. 2001) was presented in ArcView after recording with a total station, 3D pantograph and digital photography, whereas the Ferrybridge chariot burial in Yorkshire (BRADLEY 2006) was created with a realtime survey presented in ArcGIS.

Modelling Postdepositional Histories

Recording Strategy

Our recording strategy at Cisterna Grande tries to fulfil multiple functions. First of all, it produces data for the plans and sections needed in single context recording. Recording is done mostly with a total station with Italian UTM coordinates. The equipment tested in 2004 was a Nikon 350-NL with a laser pulse, but in the following years Shokkisha set 4 with data logger Husky F/S2 was found to be more reliable in local circumstances. The data is downloaded onto a Hewlett Packard laptop and transformed using the topographic measurement program 3dWin, created by the Finnish company 3d Systems. Additionally, the total station is used to measure grid points for the finds and to record special features. However, the most important features are also drawn by hand on Permatrace in order to create a traditional archive, which will preserve the key information. Due to archiving and the limited number of contexts, paper forms are still used. Digital photos are taken with 8 MB and 2 MB cameras but slides are taken as an alternative format. Another Hewlett Packard laptop is used for general data entry and the data is stored on DVDs and memory sticks.

The strategy is relatively low cost, which is essential for a small project. The data created digitally is simplified to allow efficient data entry but is sufficient for data integration. However, the strategy results in plenty of data transfer. All the Permatrace maps are scanned at Cambridge and digitised in AutoCad. The slides are also scanned and all context information is typed into an Access database.

Postdepositional Histories

The local characteristics of the geology at Cisterna Grande make the excavation of these chamber tombs unique. Numerous soft volcanic stone layers form the bedrock of the hill. These layers are relatively thin and cannot properly support tuff ceilings over the voids of the chambers. The harder rocks tend to be located nearer to the surface and the softer varieties at the depth of the loculi and the walls of the chamber. Breccia and volcanic clay are especially weak, and the latter, when moist, can be cut like butter. This weakness of volcanic layers has resulted in many chambers collapsing. Those tombs that have not collapsed have been filled by accumulating clay. The area is located on a sloping gradient, and is thus prone to the effects of winter rainfall; many of the voids were seemingly filled by mudslides and other such events. As a consequence, excavators have to remove thick layers of stone and clay. The visualisation of these collapses and accumulation deposits is one of the possibilities virtual modelling allows. The manifold postdepostitonal histories of the tombs give rise to many opportunities for creating unique models.

Collapse events and accumulation are not the only postdepositional processes affecting the tombs. Continuous ploughing since the Roman times has eroded the upper surface of the bedrock. Furthermore, the weight of the modern machinery has increased the frequency of collapses in recent times. Although one can hypothesise how much turf has disappeared from the upper walls of dromoi, it is impossible to model the entrance corridors in their full height. These uncertainties have to be taken into account when different virtual models are evaluated.

Software

Most archaeological modelling uses Autodesk AutoCad for basic data processing (cf. Lock 2003). The funding body has also provided this project with Autodesk 3D Studio Max 8. Since AutoCad Map 2003 is required for digitising by default and a professional package for virtual modelling could be used instead, the possibilities of AutoCad were not fully explored. However, it has the widest of compatibility with other packages due to its dxf format.

Apart from these two programs, Esri ArcGIS and DAZ Bryce at the Department of Archaeology at Cambridge were utilised. The ArcScene module of the former can be used in 3D visualisation. The latter is a design and animation program with the capability of creating 3D structures and landscapes. Additionally, archaeologists have lately experimented with tools designed for computer games (Anderson 2004). The Unreal Editor provided by Unreal Tournament for fieldwork-based modelling was also considered.

Both AutoCad and 3D Studio Max allow real-world co-ordinate systems and units to be set. Neither Bryce nor Unreal Editor allows this. None of Bryce's spatial axes conform to those of the UTM grid and this made it impossible to use for real-world data. However, both programs have informative online manuals (http://wiki.beyondunreal.com/wiki; http://www.daz3d.com/i.x/support/downloads/-/). These revealed the shortcomings of the programs and the limited use they have in modelling real archaeological objects.

Virtual Models of Tomb 16

A relatively shallow test subject, namely Tomb 16, was chosen to be the object of a pilot model. The tomb was excavated between 2005 and 2006, and it had a four-metre long dromos and a rounded chamber with two loculi each with a diameter of 2.5 metres. Although this tomb had not collapsed, the ceiling had to be cut off before the chamber could be excavated. Thus, it was relatively simple to model with a few deposits but it could also be reconstructed with its ceiling intact.

ArcGIS

ArcScene creates TINs out of mass points. Lines and breaklines could be used but only in relation to contours, not 3D polylines, and thus the result was not satisfactory. The walls of the chamber were too irregular for the program to join the points correctly; concave surfaces were problematic since the density of the points was arbitrary and relatively low. It became clear that the most efficient way of using the data was to use a selection of the edge points and create independent vertical and horizontal objects that would combine to create the floors of the structural elements, the walls of the dromos and the doorway. Suitable colours were to be chosen from colour palettes. This compilation gives a simplified approximation of the cut of the tomb *(Fig. 2a)*.

A simple way to visualise the postdepositional history of Tomb 16 was to create the surfaces of the main clay fills of the tomb *(Fig. 2b)*. In this way the thicknesses of the accumulations and their relationship with the depth of the chamber can be represented. Furthermore, the lack of any major collapses can be demonstrated visually. Although the model is comprehensible for those who participated in excavation, it requires explanation for those not familiar with central Italian chamber tombs.

3D Studio Max

Unlike ArcGIS, 3D Studio Max uses 3D polylines when creating surfaces. The program gives different possibilities for creating surfaces, such as extruding and creating ruled and blended surfaces. The actual modelling is very easy and quick, although all the small conjoining surfaces have to be created by hand. However, all point data has to be joined in 3D polylines in AutoCad before modelling. Furthermore, the program works best near the origin and the long UTM coordinates cannot be used directly; all edited files have to be moved nearer the origin in a similar manner, otherwise different models cannot be presented together.

All main structural elements were created separately in order to keep the amount of lines manipulated to a minimum. This also safeguards the files against corruption during the modelling. In addition, different elements can later be used in different reconstructions.

Two different models were created. The first of the two models created presents the cut of the tomb as it was at the end of the excavations, all opened and emptied *(Fig. 3a)*. The real textures created using material samples from the excavation photos could be used to render the model. In order to show different textures, not all elements were joined properly in one object. This model, with its differing tuffs

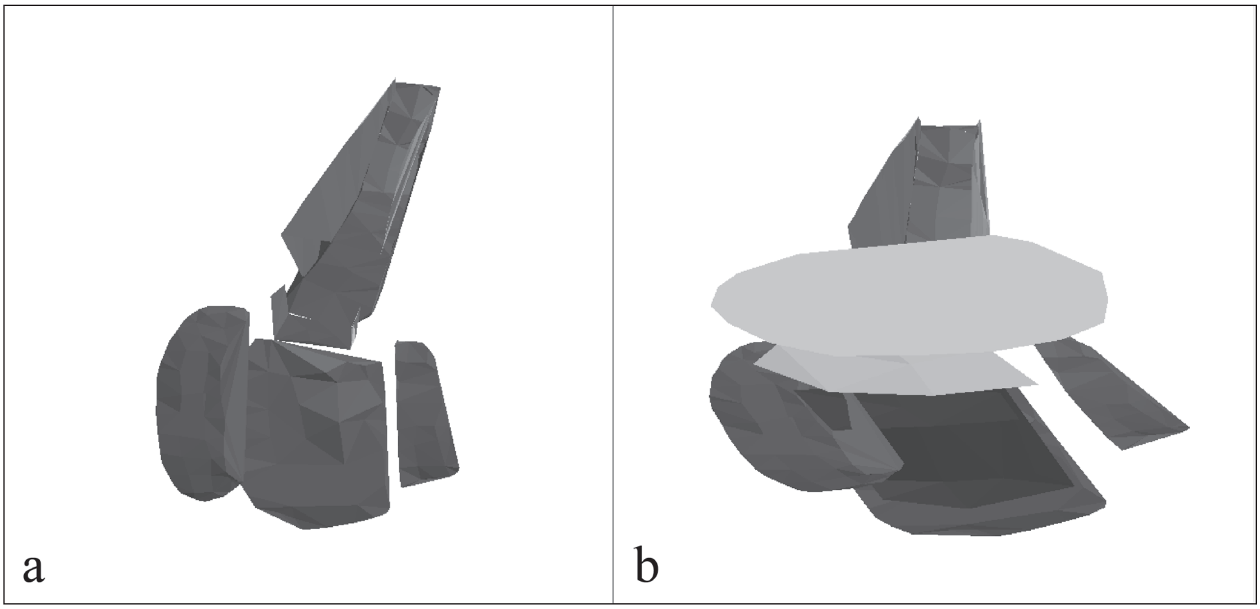

Fig. 2. a. The model of the cut of Tomb 16 in ArcScene (viewed from west). b. The model with the original tuff surface and the surfaces of different fills (viewed from west).

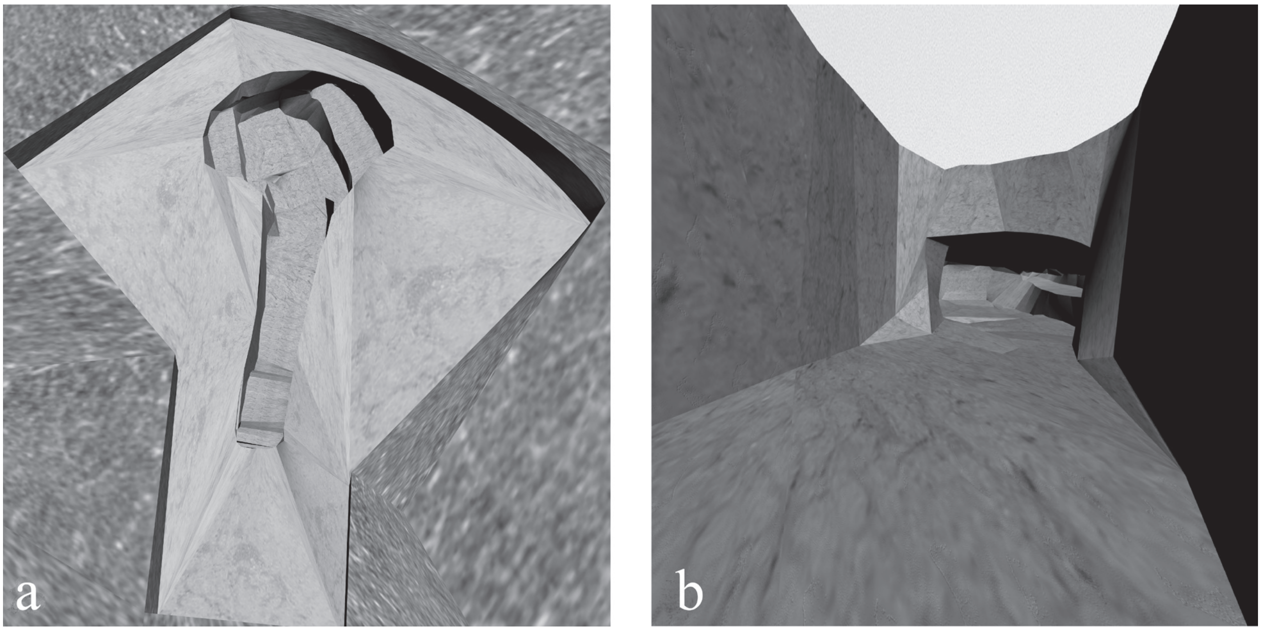

Fig. 3. a. The model of the cut of Tomb 16 in 3D Studio Max (viewed from southeast). b. A view into the reconstructed chamber (viewed from east-northeast).

and sunburnt grass, recreates the last phase in the postdepositional history of Tomb 16.

The second model is the reconstruction of the tomb as it was just before any deposits were made *(Fig. 3b)*. This model represents the starting point of the depositional and postdepositional history of the tomb. Further elements, for example, the door slab and other blocking features, can be added as they are modelled.

Discussion and Conclusions

The Archaic chamber tombs excavated at Cisterna Grande have been altered by postdepositional events and processes. Many of the tombs have collapsed due to the local geology and other contributing factors. They, and other tombs cut open for the excavation, have lost their original architectural form. Digital recording together with virtual modelling allows reconstruction not only of the cut of the tomb but of different funerary deposits and features created during the postdepositional history of a tomb.

Comparisons were made between the usability of different software when modelling with original georeferenced data. It soon became obvious that the design software Bryce and game engine Unreal Editor fare poorly in comparison with AutoCad, ArcGIS and 3D Studio Max, which allow the setting of different grids and units. However, 3D Studio Max performs poorly when large, real-world UTM coordinates are used and requires data to be moved nearer to the origin. On the other hand, it allows the creation of realistic textures out of samples of original digital data, something neither ArcGIS nor AutoCad can do.

AutoCad is indispensable in checking and editing field data. When considering the two programs used in proper modelling, the differences in the way they use measurements have to be acknowledged. ArcGIS creates TINs from mass points and 3D Studio Max rules and blends surfaces from 3D polylines. However, an automated TIN creation of a chamber tomb in ArcScene would require a point density much denser than in our data, whereas the simplified data is sufficient for 3D Studio Max. ArcGIS can be used in creating simplified visualisations, whereas 3D Studio Max allows the reconstruction of pseudorealistic replicas. The modelling requires data editing in both programs but the end products are different. ArcGIS with ArcScene is at its best when creating two-dimensional illustrations of three-dimensional models. 3D Studio Max, however, is better suited for more complicated work and creating interactive models and animations. Both can be used in modelling postdepositional histories with relative ease but the end products vary in quality. As a professional product, 3D Studio Max offers greater possibilities for the visualisation of the history of a tomb. This program also makes the best use of the data created by compromising between accuracy and efficiency.

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